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(54) Title: LOAD-BEARING STRUCTURES

(57) Abstract

A load bearing element is extruded from a thermoplastic plastics material which is preferably a recycled material such as printed packaging formed, preferably of biaxially oriented polypropylene and is compounded so that the element has a flexural modulus of 4000 MPa or above.

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INTERNATIONAL SEARCH REPORT

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

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LOAD-BEARING STRUCTURES

This invention relates to static and dynamic load-bearing structures, in particular but not exclusively to structures for walking on or for retaining wet concrete. The invention relates in particular to scaffold boards, formwork beams and formwork panels.

Scaffold boards and formwork have traditionally been made of wood. Conventional wooden boards used in the construction industry have a gross weight in the range of from about 17 to 30 kg. They are thus heavier than might be desired for handling by a single person and are themselves environmentally undesirable insofar as they represent use of only slowly renewable resources. Cheaper and more rapidly renewable forms of timber are generally unsuitable for reasons, *inter alia*, of strength. However, all wood boards, formwork panels and beams are subject to degradation caused by entry of water. This leads to deterioration of mechanical character, warping and cracking. Particular problems in the tropics are excessive warping because of elevated temperatures and that of attack by insects, for example termites. For this reason, timber boards utilised at outside locations tend only to have a useful life of from about six months to about 15 months.

A further problem with wood scaffolding boards is that timber has a roughish surface in which water can accumulate. This can prove a significant problem under icy conditions when the existence of ice will be difficult to identify and can lead to accidents. Even under normal conditions, the coefficient of friction of wood surfaces is somewhat low and can make scaffold boards slippery, especially when wet. Moreover, a common general problem at building sites is the theft, inter alia, of scaffold boards and formwork panels. The best that has been achieved hitherto with timber

scaffold boards in countering their theft has been to apply a rough printing to the board by continuous rubber stamping or to paint the ends of the board using a characteristic colour combination. The first type of security measure may be difficult to observe and the second can be readily circumvented by a thief merely by sawing off the ends.

It is an object of the present invention to provide a low cost alternative to a wooden scaffold board or formwork screen panel of conventional type which, as much as possible, is free from the problems set out above.

According to one aspect of the present invention, there is provided a load bearing structural element formed from a preferably recycled thermoplastic plastics material which is compounded so that the element has a flexural modulus of 4000 MPa or above.

Preferably, the flexural modulus is 5500 MPa or above.

A characteristic feature of the material used to form structural elements embodying the invention is flexural modulus, also known as flexural stiffness or elastic modulus. This can be predicted by supporting the structural element across its recommended maximum span, applying a centred load and using the following equation:

$$E = \frac{F(2L^3-Lb^2+(b^3/4)}{96yi}$$

where:

E = Elastic modulus (in Pascals)

F = Load (in Newtons)

i = 2nd moment of inertia of structural element's cross section (in m^4)

L = Span (in metres)

b = Centred space of load distribution (in metres)
y = maximum deflection, absolute value (in metres).

Similar results can be obtained from a distributed load such as would be experience by formwork.

Thus, it is readily possible to establish whether a material will enable a structural element produced therefrom to possess a flexural modulus as required by the present invention.

For a narrow scaffold board having an external maximum section of 230 x 45 mm and a length of 3900 mm, when:

$F = 1500$ N
$i \leq 12 \times 10^{-7}$ in m^4
$L = 1.5$ m
$b = 0.5$ m
$y \leq 0.015$ m,

duration of load = 168 hours

the flexural modulus will be greater than 5500 MPa.

The flexural modulus (elastic modulus) of a structural element embodying this invention can be calculated from the deflections. Rods made of the compositions and having a diameter of less than 35 mm are simply supported across a span greater than 340 mm. A sustained load of 31 kilograms is applied to the centre of the rods so that the "ultimate elastic modulus" is considered to be reached when deflection remains unchanged for five days under a constant temperature of 45 °C.

Preferably, a structural element in accordance with the present invention has a ratio of flexural modulus (in Megapascals) to density (kg/m^3) of at least 2.5:1. Preferably, the ratio is at least 3:1, more

preferably at least 4.2:1.
The density of a particular structural element can be easily determined and, using the equation above, the ratio can be easily calculated.

Thus, for a narrow scaffold board having an external maximum section of 230 x 45 mm and a length of 3900 mm mentioned above, which has a density of less than 1300 kg/m^3, the ratio of flexural modulus to density will be 4.2:1.

Structural elements in accordance with the invention can have a stiffness which exceeds the deflection standards set out in European draft legislation EN12811, a creep which satisfies creep standards established by the European Health & Safety Executive over an ambient temperature range of -20 to 50°C, an impact resistance in excess of standards set by the European Health & Safety Executive and as measured at a temperature of -20°C and which has twice the impact strength of dry timber at 20 °C. Preferably, the element meets the specification for a timber scaffold board as described by BS2482:1971

In accordance with the present invention, there is provided a structural element which preferably comprises an extruded plastics composition which comprises 30-90 wt% of thermoplastic polymer, and 10-60 wt% of elastic modulus increasing material.

Preferred amounts of the respective materials are 40-75 wt%, more preferably 50-65 wt%, of thermoplastic polymer, and 25-50 wt%, more preferably 30-45 wt%, of an elastic modulus increasing material.

The thermoplastic polymer may be polyethylene, polypropylene, or polyethylene terephthalate. However, in general, polypropylene is better at resisting creep and is better able to resist lower temperatures, having an operating range generally of -20 + 45°C. The polypropylene is preferably bi-axially oriented

polypropylene (BOPP), which is a common material in packaging and has a low cost for recycling purposes, especially if contaminated with printing inks whose presence precludes most conventional processing techniques.

The elastic modulus increasing material may be glass beads, talcum powder, etc, but it is preferred if it is glass fibres. Such glass fibres are preferably recycled glass fibres because of cost considerations and it is even possible to use glass fibre "fluff". It is preferred if the glass fibres have a length of greater than about 5mm, preferably in the range 8-12 mm, in order to provide the product with additional rigidity.

To enhance the elastic modulus further, the composition may additionally comprise a coupling agent, to enhance bonding between polymer and elastic modulus increasing material and/or a nucleating agent, the latter ensuring a uniform compact microcrystalline structure, in relatively low amounts, such as 1 to 3, preferably 2 wt%, and from 0.1 to 2 wt%, preferably 0.5 wt%, respectively.

Polymer materials employed in the production of product, especially board structures, embodying the invention may have incorporated therein in particular, fire retardants, UV stabilisers and friction increasers. In this way, there is readily obtained a material which is not easy to ignite according to BS476, part 12 and having a low surface spread of flame when tested to BS 476, part 7. The materials utilised can be compounded so as to ensure low emission of toxic fumes in a fire, low emission of smoke in a fire and absence of molten droplets in a fire. Some of these requirements cannot be met by, or are inappropriate for, wooden scaffold boards. Others are potential problems when using plastics materials, which problems

are readily addressed by suitable compounding.

Such materials are preferably present in an outer layer on the product or board which may have a thickness of up to 1 mm, preferably 0.5 mm.

Mention has already been made of problems of slipping on timber scaffold boards. This problem can readily be addressed in the practice of the present invention when, instead of producing the board material as a single extrusion, it is produced as a co-extrusion with an anti-slip surface being provided thereon. For this purpose a thermoplastic polyethylene or polyolefin material such as EPDN or TPO may be provided. Such layer can also contain the other additives mentioned hereinabove as suitable for inclusion in a co-extruded outer layer or be a separate layer. Such a material is however not suitable for use alone because of its inability to meet structural requirements.

A preferred composition of the outer layer comprises up to 80 wt%, preferably about 52 wt%, of thermoplastic olefin (TPO) and up to 20 wt %, preferably 10 wt%, of low density polyethylene (LDPE) which provide anti-slip properties on for example scaffold boards. Such layers, in addition, provides for easy release of concrete where formwork boards and panels such layers also protecting the board or panel front abrasion and scuffing and weaknesses that may be caused by scratching or impact. In addition, the composition may have 25 wt% of a brominated organic compound such as decabromodiphenyl oxide and 12.5 wt% of SbO_3 as flame retardants. A pigment may be added to 0.5 wt%, and a UV additive such as tinuvin to 0.5 wt%.

The structural elements in accordance with the present invention can also be used for decking, system batons, access platforms, boardwalks, walkways, piers, jetties, staging, shuttering, lintels, shelving, telegraph poles, pallets, road humps, fencing,

barriers, seating, benches etc. However, the invention will be described hereinafter primarily with reference to scaffold boards.

Such boards can readily be made by a continuous extrusion process and cut to length so as to be compatible with timber scaffold boards which generally are available in lengths of 3.9 metres, 3.0 metres and 2.4 metres, in each case ± 20 mm and having a width of 225 mm ± 2 mm and a thickness of 45.5 mm ± 0.5 mm. Generally, such planks or boards embodying the invention will be hollow and to ensure that they satisfy the aforementioned physical parameters, they may be provided with internal walls extending longitudinally thereof.

Many advantages are attainable with boards embodying the invention. Firstly, there is a considerable weight reduction. A 3.9 metre long board which is to bridge a 1.5 metre span may have a weight of 18.3 kg compared with 24 kg for a wet timber board. If only a 1.2 metre span has to be bridged, then such a board may be made so as to have only a weight of only about 16.8 kg.

Mention has also been made herein of the restricted lifetime of timber boards. With recycled plastics material, it is possible to produce boards having a life which is a minimum of three times that of timber. No preservative or treatment is required as there will be no susceptibility to fungicidal rot or termite attack. Warping or bowing will not occur and unless the board is severely mistreated, there will be no splintering. The boards are also resistant to acids, alkalis, solvents, detergents, greases and oils which degrade wooden scaffold boards. Resistance to chemicals in concrete is advantageous for formwork applications.

Boards embodying the invention will be free from

hazardous metal plates as are generally used as end protection on wooden scaffold boards and formwork girders. Extrusion methods make it possible to produce radiussed edges. In addition to the safe handling thus made possible, the ends of hollow scaffold boards can be closed off by tightly fitting injection moulded end caps knocked firmly into the open ends of the profile before it has fully cooled down after extrusion. These end caps can be manufactured from unbreakable and resilient plastic material and in a colour which may be indicative of the source of the plank. They can also be employed as water-tight connectors between formwork panels. Better security against theft can be achieved by providing a coloured bead co-extruded along the plank, or continuously embossing or hot foil stamping the name of the owner along the plank possibly on both major faces. These cannot be removed without damaging the plank. Each owner may employ a characteristic colour or pattern. In addition, an embossed tread pattern may be applied to the major faces of the plank.

In addition to providing a co-extruded anti-slip surface, it is possible for an anti-slip surface texture to be embossed or moulded into one or both opposite surfaces of the plank, the surface texture being designed to satisfy or exceed appropriate coefficient of friction standards.

Extrusion of mixes of materials to be utilised in the production of the planks or boards may take place using a high efficiency venting screw such as a Ventus screw. Additionally, one can utilise a rotary channel pump according to WO97/42019 for dosing into an extruder consistent quantities of particulate material such as recycled polymer material, in particular chopped film which may be printed film, ie. low grade material, but not liquid or powder. Such a dosing method avoids granulation of plastics material.

In order to achieve a product with relatively long glass fibres in it, it is necessary to add these fibres after working by the extruder screw used in compounding the material for the board which would otherwise fragment glass fibres to too great an extent. Dispensing of glass fibres and other solid material into matrix passing through the downstream portion of an extruder may be achieved using a flow pump according to EP-A-0467842 for transferring and compacting particulate solids. The glass fibres are also preferably oriented in planes parallel to a load bearing surface thereof by passage through a known multi-layer grid producing multi-layering of glass fibres in the extrudate obtained. This ensures a maximum strength of product. It has also been found that the stiffness of the product is improved if the glass fibres are not of a uniform length.

For a better understanding of the invention and to show how the same can be carried into effect, reference will now be made by way of example only to the accompanying drawings wherein:

Figure 1 shows a set of boards embodying the invention, these being shown in cross-section and each board having an internal web thickness of 5 mm;

Figure 2 is a bar chart showing the results of impact tests on prior art scaffold planks and scaffold planks embodying the invention; and

Figure 3 is a graph of deflection against time for one board embodying this invention.

Referring to Figure 1, there is shown a series of extruded boards embodying the invention and having the following dimensions and weights.

a) plastics toe-board 150 mm x 25 mm in cross-section with 4 mm external wall thickness, the board having a length of 2.49 metres max. and a weight of 3.8 kg.

b) plastics plank 225 mm x 45 mm in cross-section with an external wall thickness of 6 mm and a maximum length of 3.9 m, the plank to be supported at 1.2 m max. centres and having a weight of 14.9 kg.

c) plastics plank 225 mm x 45 mm in cross-section with 7 mm wall thickness and 3.9 m long, to be supported at 1.5 mm max centres, the plank having a weight of 18.3 kg.

d) plastics plank 225 mm x 52 mm in cross-section with 7 mm wall thickness and 3.9 m long, to be supported at 1.8 max centres. The plank has a weight of 19.8 kg.

e) plastics plank 300 mm x 52 mm in cross-section with 7 mm wall thickness and 3.9 m long, to be supported at 1.8 m max centres. The plank has a weight of 24.8 kg.

f) plastics plank 225 mm x 65 mm in cross-section with 7 mm wall thickness and 2.4 m long to be supported at 2.4 m max centres. The plank has a weight of 13.1 kg.

g) plastics system scaffold batten 375 mm x 65 mm in cross-section with 7 mm wall thickness and 2.4 m long, to be supported at 2.4 m max centres. The batten has a weight of 18.5 kg.

h) plastics system scaffold batten 320 mm x 85 mm in cross-section with 7 mm wall thickness and 3.0 m long, to be supported at 3.0 m max centres, the batten having a weight of 23.8 kg.

Boards were manufactured from mixtures having the following compositions:

- Boards a), b) and boards the same as board b) except for a wall thickness of 7 mm

Masterbatch	5 wt%
Biaxially oriented polypropylene (BOPP)	65 wt%
Glass fibre	30 wt%

- Boards the same as board b) but intended to be supported at 1.5 m centres, and such boards with a wall thickness of 7 mm:

Masterbatch	5 wt%
BOPP	53 wt%
Glass fibre	42 wt%

- Boards the same as board f) except for a wall thickness of 6 mm, a length of 3.9 m and intended to be supported at 1.8 m centres; such boards with a wall thickness of 7 mm; board g); boards the same as board g) except for a wall thickness of 6 mm:

Masterbatch	5 wt%
BOPP	55 wt%
Glass fibre	40 wt%

- Board f) and boards the same as board f) except for a wall thickness of 6 mm:

Masterbatch	5 wt%
BOPP	50 wt%
Glass fibre	45 wt%

In each of the above cases, the masterbatch comprises:

Polypropylene	2.8 parts by wt
Coupling agent (maleic anhydride)	2 parts by wt

nucleating agent (MDBS)	0.2 part by wt

It will be appreciated that the amount of glass fibre in the composition is increased when increased stiffness is required, for example, when the boards are intended to be used across larger spans.

Each of the above boards was co-extruded with an 0.5mm thick outer layer which comprises the following:

Thermoplastic olefin (TPO)	51.5 wt%
LDPE	10 wt%
flame retardant (decabromodiphenyl Oxide)	25 wt%
flame retardant (SbO_3)	12.5 wt%
pigment	0.5 wt%
UV additive	0.5 wt%

Tests have been carried out on boards embodying the invention as follows:-

1. **Impact test**

Testing to new standards proposed by the European Health & Safety Executive, a 50 kilogram dead weight of sand was dropped on to the centre of a plank supported at 1.3 metre centres and lightly restrained at each end. It was required that the board be able to withstand an impact energy of 600 joules. A total of 5 boards were employed. A wet timber scaffold board failed at an impact energy of about 390 joules. Two different dry timber scaffold boards failed at about 590 joules although audible cracks were heard at about 490 joules. A first board embodying the invention did not fail until subject to an impact energy of about 780 joules while a second plastics board did not fail until subject to an impact energy of about 870 joules. The results are illustrated graphically in Figure 2.

2. **Deflection Boards**

A board embodying the invention was tested to a new standard proposed under BS draft document EN12811 and HD1000. For this purpose, measurement was made of the deflection caused by a load of 1.5 KN applied to an area of 500 mm x 230 mm at the centre of the board, with the board supported between 1.5 metre centres. It is a requirement that deflection must not exceed 1% of the span (a maximum of 15 mm). Measurements were carried out daily after extrusion and cooling. The plank utilised is made of the plastic sample of the second plastics board utilised in the impact test. Deflection values were measured daily and are shown in Figure 3 of the accompanying drawings for which it can be seen that immediate application of the load achieved a deflection of 9.2 mm which increased by another 1 mm over one hour and levelled off at 11.2 mm over the next three days. Upon removal of the loading, a residual deflection of 2 mm was recorded.

3. **Strength Test**

The superior high temperature strength of plastic boards embodying this invention is demonstrated by results of a test specified by draft European standard EN12811, conducted by the Health & Safety Laboratory. The test involved a sample spanning 1.5m in an environment maintained at 40°C, undergoing a centred static load evenly distributed over 0.5m.

A load pf 594kg broke a standard timber board. A load of 1015kg did not break a plastic board.

CLAIMS

1. A load bearing structural element extruded from a thermoplastic plastics material which is compounded so that the element has a flexural modulus of 4000 MPa or above.

2. An element as claimed in claim 1, which has a flexural modulus of 5500 MPa or above.

3. An element as claimed in claim 1 or 2, which has a ratio of flexural modulus (in Megapascals) to density (in kg/m^3) of at least 2.5:1.

4. An element as claimed in claim 3, wherein said ratio is at least 4.2:1.

5. An element as claimed in any preceding claim, which comprises from 30-90 wt% of thermoplastic polymer and 25-50 wt% of an elastic modulus increasing material.

6. An element as claimed in any preceding claim, wherein the thermoplastic polymer is polyethylene, polypropylene or polyethylene terephthalate.

7. An element as claimed in claim 6, wherein the thermoplastic polymer is bi-axially oriented polypropylene.

8. An element as claimed in any preceding claim, wherein the thermoplastic plastics material is a recycled material.

9. An element as claimed in any preceding claim which contains glass fibres as an elastic modulus increasing

material.

10. An element as claimed in claim 9, wherein the glass fibres have a length of at least 5mm.

11. An element as claimed in claim 10, wherein the glass fibres have a length of 8-12mm.

12. An element as claimed in claim 9, 10 or 11, wherein the glass fibres are oriented in planes parallel to a load bearing surface thereof.

13. An element as claimed in any preceding claim, which has compounded with the thermoplastic plastics material one or more substances selected from fire retardants, UV stabilisers and friction increasers.

14. An element as claimed in any preceding claim which has one or more substances selected from fire retardants, UV stabilisers and friction increasers present in an outer layer which has a thickness of up to 1mm.

15. An element as claimed in claim 14, wherein the outer layer is formed from thermoplastic plastics material containing said substance(s) and co-extruded with the remainder of the material forming said element.

16. An element as claimed in any preceding claim, which has a co-extruded outer layer which has anti-slip character.

17. An element as claimed in any preceding claim wherein the compounded thermoplastic plastics material contains a coupling agent and/or a nucleating agent in

amounts of from 1 to 3 wt% and 0.1 to 2 wt% respectively.

Fig. 1a

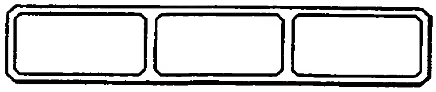

Fig. 1b

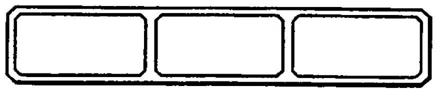

Fig. 1c

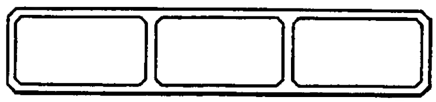

Fig. 1d

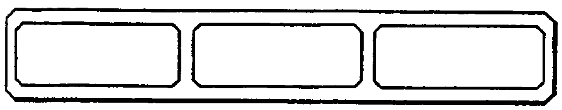

Fig. 1e

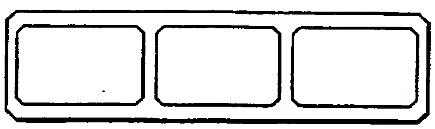

Fig. 1f

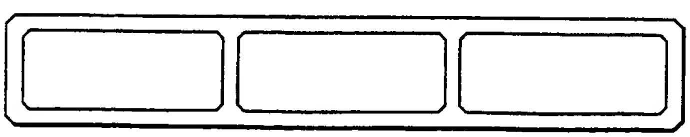

Fig. 1g

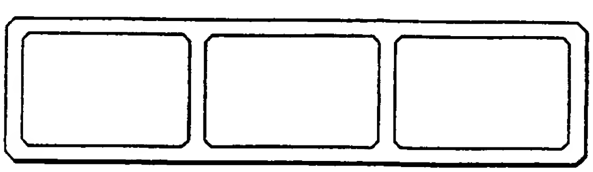

Fig. 1h

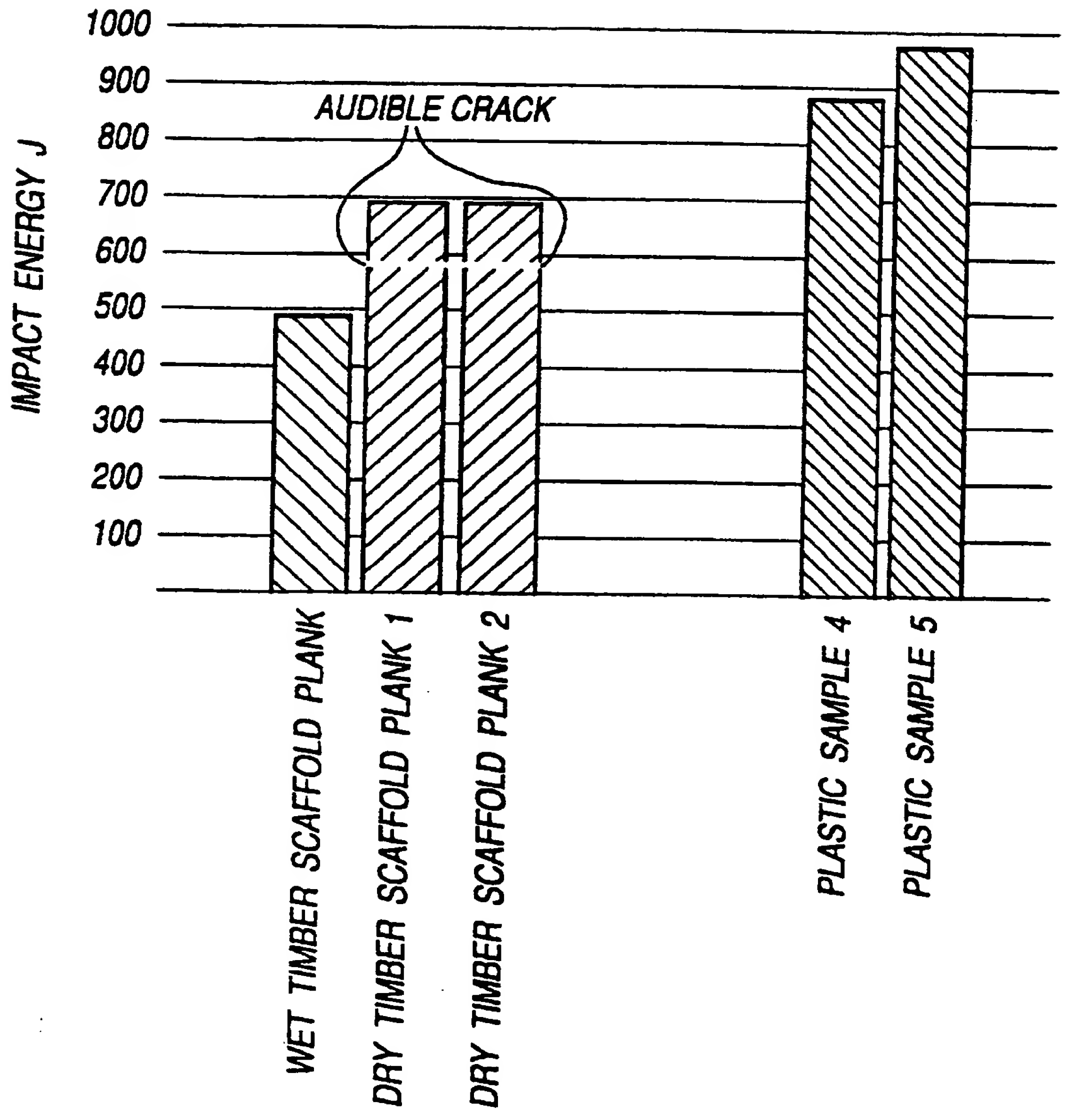
1000
900
800
700
600
500
400
300
200
100
IMPACT ENERGY J
AUDIBLE CRACK
WET TIMBER SCAFFOLD PLANK
DRY TIMBER SCAFFOLD PLANK 1
DRY TIMBER SCAFFOLD PLANK 2
PLASTIC SAMPLE 4
PLASTIC SAMPLE 5

Fig.2

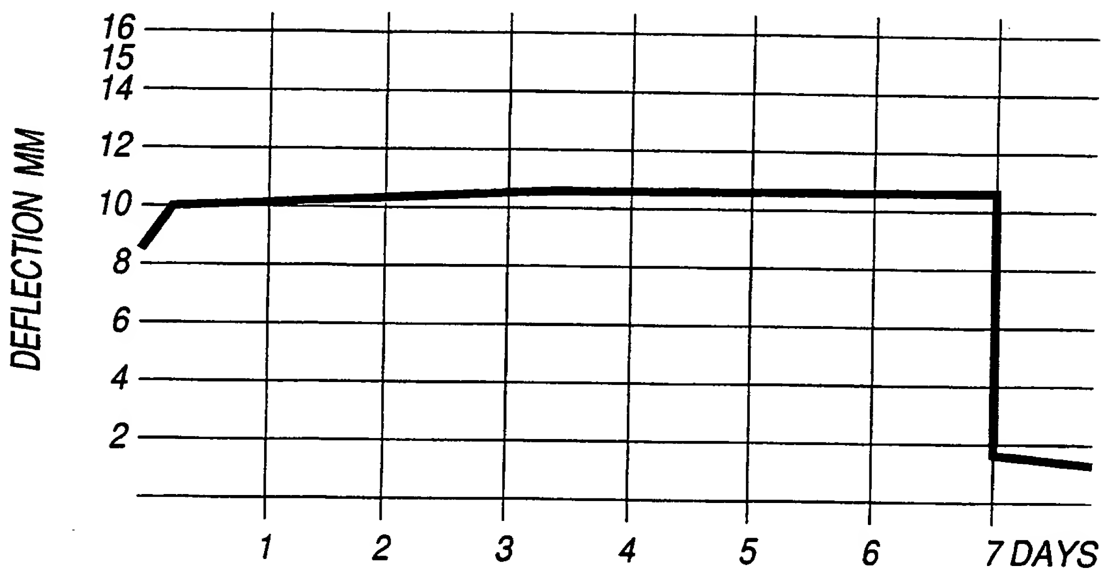

Fig.3